**ANALYSIS OF "MIDNIGHT" TRACKS IN THE STARDUST INTERSTELLAR DUST COLLECTOR: POSSIBLE DISCOVERY OF A CONTEMPORARY INTERSTELLAR DUST GRAIN.** A. J. Westphal[1], C. Allen[2], S. Bajt[3], R. Bastien[2], H. Bechtel[4], P. Bleuet[5], J. Borg[6], F. Brenker[7], J. Bridges[8], D. E. Brownlee[9], M. Burchell[10], M. Burghammer[5], A. L. Butterworth[1], P. Cloetens[5], G. Cody[11], T. Ferroir[12], C. Floss[13], G. J. Flynn[14], D. Frank[2], Z. Gainsforth[1], E. Grün[15], P. Hoppe[16], B. Hudson[17⋆], A. Kearsley[18], B. Lai[19], L. Lemelle[12], H. Leroux[20], R. Lettieri[1], W. Marchant[1], A. Nanz[21⋆], L. R. Nittler[11], R. Ogliore[1], F. Postberg[15], S. A. Sandford[22], S. Schmitz[7], G. Silversmit[23], A. Simionovici[24], R. Srama[15], F. Stadermann[13], T. Stephan[25], R. M. Stroud[26], J. Susini[5], S. Sutton[25], R. Toucoulou[5], M. Trieloff[15], P. Tsou[27], A. Tsuchiyama[28], T. Tyliczszak[5], B. Vekemans[29], L. Vincze[29], J. Warren[3], S. Wagner[29⋆], D. Zevin[1], M. E. Zolensky[3], >27,000 Stardust@home dusters[30⋆], [1]*Space Sciences Laboratory, U. C. Berkeley, USA,* [2]*KT NASA Johnson Space Center, USA,* [3]*DESY, Hamburg, Germany,* [4]*Advanced Light Source, Lawrence Berkeley Laboratory, USA,* [5]*European Synchrotron Radiation Facility, Grenoble, France,* [6]*IAS Orsay, France,* [7]*Geoscience Institute, Universität Frankfurt am Main, Frankfurt, Germany,* [8]*Space Research Centre, University of Leicester, Leicester, UK,* [9]*Astronomy Dept., University of Washington, USA,* [10]*University of Kent, UK,* [11]*Carnegie Institution of Washington, USA,* [12]*ENS, Lyon, France,* [13]*Physics Dept., Washington University, USA,* [14]*Dept. of Physics, SUNY – Plattsburgh, USA,* [15]*Institute of Earth Sciences, University of Heidelberg, Germany,* [16]*Max-Plank-Institut für Chemie, Germany,* [17]*Midland, Ontario, Canada* [18]*IARC, Dept. of Mineralogy, The Natural History Museum, UK,* [19]*Advanced Photon Source, Argonne National Laboratory, USA,* [20]*Université des Sciences et Technologies de Lille, France,* [21]*Escondido, CA, USA* [22]*Astrophysics Branch, NASA-Ames Research Center, USA,* [23]*University of Ghent, Belgium,* [24]*Observatoire des Sciences de l'Univers de Grenoble, France,* [25]*University of Chicago, USA,* [26]*Naval Research Laboratory, Washington DC, USA,* [27]*Jet Propulsion Laboratory, USA,* [28]*Osaka University, Japan,* [29]*Hessen, Florstadt, Germany,* [30] *Worldwide* ⋆*Stardust@home duster*.

**Introduction:** In January 2006, the Stardust sample return capsule returned to Earth bearing the first solid samples from a primitive solar system body, Comet 81P/Wild2, and a collector dedicated to the capture and return of contemporary interstellar dust. Both collectors were $\sim$0.1 m$^2$ in area and were composed of aerogel tiles (85% of the collecting area) and aluminum foils. The Stardust Interstellar Dust Collector (SIDC) was exposed to the interstellar dust stream for a total exposure factor of 20 m$^2$·day [1]. The Stardust Interstellar Preliminary Examination (ISPE) is a three-year effort to characterize the collection using non-destructive techniques. The goals and restrictions of the ISPE are described in [2,3]. A summary of analytical techniques is described in [4].

**Off-normal tracks** Through the Stardust@home distributed search project, volunteers have so far identified 28 particle tracks in the aerogel collector, all of them off-normal. The distribution of azimuth angles is shown in Fig. 1.

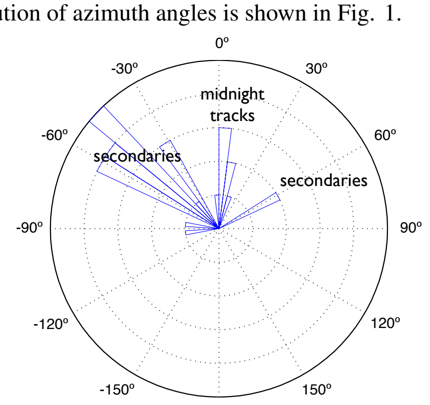


Fig. 1: Rose diagram of trajectories of off-normal tracks.

The azimuth angle $\phi$ of a track is the angle between two vectors: the projection of the track trajectory onto the plane of the collector, and the vector from the attachment point of the tray to the top of the collector, that is, the edge furthest from the spacecraft. Tracks with azimuth angles in the range $\sim 20^\circ < |\phi| < \sim 100^\circ$ are consistent in their trajectories with an origin as secondary ejecta from the spacecraft solar panels. Such an origin has been confirmed by synchrotron X-ray microprobe analysis of a subset of these tracks [4]: the captured particles contain high concentrations of Zn and Ce, consistent with the composition of the glass covers of the solar panels. There is, however, a possibility that some of particles in this general population are extraterrestrial. Because the interstellar collector was articulated during the exposures to track the $\beta = 1$ interstellar dust stream, the trajectories of some particles would trace back to the solar panels if they had been captured at one collector position, and track back to space if they had been captured in another. Since there is no way to know when particles were captured, there is an inherent ambiguity in the origin of these tracks. ($\beta$ is the ratio of radiation force to gravitational force.) No off-normal tracks have been found so far in a searched area of 247 cm$^2$ that have trajectories that unambiguously point to a direct extraterrestrial origin (i.e., with azimuth directions in the range $\sim 100^\circ < |\phi| < 180^\circ$.

**"Midnight" tracks**: A population of seven tracks with $|\phi| < \sim 20^\circ$ (so-called "midnight" tracks) are consistent in their trajectories with an origin in the interstellar dust stream (for particles with $\beta \sim 0$), or with secondaries from an impact or impacts on the lid of the sample return capsule (SRC). Again, the ambiguity is due to the articulation of the collector during exposure. The tracks are not carrot-like but are similar to tracks formed in laboratory experiments at $> 10$ km sec$^{-1}$ at Heidelberg [5]. To determine the origin of these particles, we extracted four of them in keystones and picokeystones [6], mounted them in silicon nitride sandwiches [4], and analyzed them on the X-ray fluorescence microprobe ID13 at the European Synchrotron Radiation Facility (ESRF), on the X-ray fluorescence microprobe 2-ID-D at the Advanced Photon Source (APS), and on the scanning X-ray transmission microprobe

11.0.2 at the Advanced Light Source (ALS). Optical images of the tracks after extraction are shown in Fig. 2.

I1004,1,2 was analyzed on SXRF beamline 2-ID-D at the APS and at STXM 11.0.2 at the ALS. Analysis at the APS showed that Cr/Fe, Mn/Fe, Ni/Fe, and Cu/Fe in this particle are significantly enriched relative to CI. S/Fe, Ca/Fe, and Ti/Fe are all significantly below CI. We conclude based on the composition that this particle is unlikely to have a purely extraterrestrial origin. The unusually high density of the aerogel and thickness of the keystone precluded STXM analysis of most elements in this keystone.

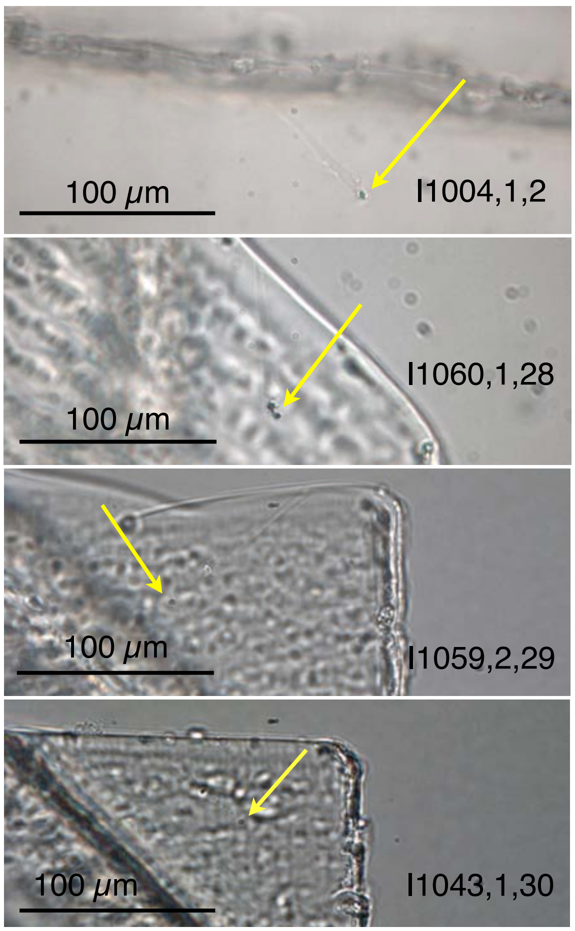


Fig. 2: Optical images of tracks I1004,1,2; I1060,1,28; I1059,2,29; I1043,1,30. Arrows point to terminal particles.

XRF measurements on ID13, I1060,1,28 showed very high enrichments of Cu and Zn with respect to Fe, normalized to CI abundances. We conclude that this particle has a likely origin as a secondary from an impact on the SRC lid.

I1059,2,29 did not show any measurable concentration of heavy elements in the fluorescence analysis on ID13, nor any XRD spot. It is possible that this projectile is purely organic or is a secondary from an impact on the SRC lid. This candidate will be analyzed by STXM on the 11.0.2 beamline at the ALS in early 2010. This beamline is sensitive to light elements C, N, O, Na, Mg, and Al.

**I1043,1,30: a candidate interstellar dust particle:** The most promising interstellar dust candidate found to date is track I1043,1,30. Preliminary examination of the fluorescence analysis on ID13 yield CI ratios for Mn/Fe, close to CI for Cr/Fe and Ni/Fe, somewhat lower values for Ca/Fe and higher for Cu/Fe and Se/Fe. The Se signal seems to originate from the compressed aerogel cover in front of the impacting grain [7]. Detailed elemental maps (Fig. 3) and XRD screening shows that this particle consists of hundreds of Fe,Ni-rich grains, embedded in a Ca,Si,Mn-rich matrix. Cr seems quite uniformly distributed over the whole grain. Some Fe,Ni rich areas are enriched in Cu as well. The Si distribution shows a gap where the Fe,Ni concentration and the Compton signal gave the highest values indicating Fe,Ni metal, Fe, Ni sulfide or Fe,Ni oxide as likely candidates. The complex nature of this particle with Fe,Ni rich grains embedded in a Ca, Mn, Si-rich matrix resembles the structure of GEMS, although the nature of the matrix chemistry is different from GEMS-like material found in cometary tracks [8]. We caution that our current understanding of capture effects in aerogel at $\sim$20 km sec$^{-1}$ is rather primitive, so any inference of the structure of the original impactor would be premature. Further investigation of this track is in progress.

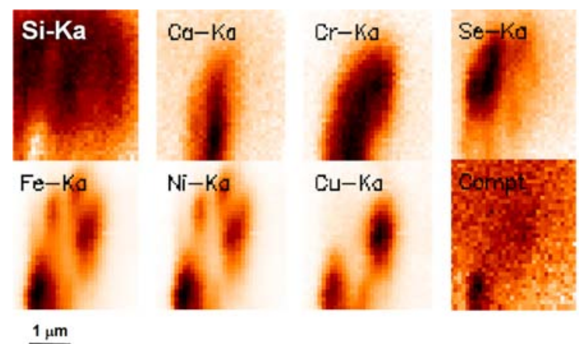


Fig. 3: X-ray fluorescence and Compton map of I1043,1,30.

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